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ORIGINAL RESEARCH

EFFECTS OF A DRY-LAND STRENGTHENING PROGRAM IN COMPETITIVE ADOLESCENT SWIMMERS

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ABSTRACT

Background: Shoulder pain is common in competitive young swimmers. A relationship between shoulder strength and shoulder soreness in competitive young swimmers may indicate need for strengthening.

Purpose*:* To determine if a shoulder exercise program will improve shoulder strength and decrease pain in competitive young swimmers.

Study Design: Randomized control

Methods: Participants (10 control, 11 experimental), randomly assigned to a control or experiment group, completed the 12 week program. Strength was measured prior to the study for shoulder flexion, abduction, external rotation, internal rotation, and extension on the dominant arm using handheld dynamometry. The experimental group was then assigned exercises to be performed three times per week. The control group was instructed not to perform the exercises. All participants were re-tested at six and twelve weeks following initiation of the study.

Results: The changes in strength for each muscle group and pain were compared between groups using a mixed design two-way ANOVA. The experimental group significantly increased external rotation strength compared to the control group. Shoulder soreness was not significantly different between groups.

Conclusion: Adolescents who perform shoulder strengthening significantly increased their external rotation strength compared to adolescents who only participated in a regular swimming regimen.

Key words: Competitive swimmer, rotator cuff strength, soreness, adolescent, external rotation. Randomized controlled trial

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INTRODUCTION

Swimming is an activity that is growing in popularity as a competitive sport in the United States[1,2] with registered swimmers in the USA Swimming Association reaching 349,000 as of 2014 .[3] Due to this increasing interest, sport-related injuries are also on the rise. Competitive year round swimmers cover 6,000 to 14,000 meters (m) a day in practice, while some distance swimmers cover as far as 24,000 m a day during practice.[4-8] Practices are generally held five to seven days per week, oftentimes twice daily up to 3 times per week. This equates to roughly 60,000 to 80,000m of total swimming distance per week.[4-8] This exercise volume can result in the development of shoulder pain. Shoulder pain is among the most frequent complaints of competitive swimmers with the incidence of shoulder pain in competitive swimmers ranging between 3-80%.[1,4,8-13] *Swimmers' shoulder* is a common term used to describe anterior shoulder pain that occurs during swimming or after workouts.[12] More recently the term *swimmers' shoulder* has been thought to indicate the underlying cause of pain, not just anterior shoulder pain in general. These causes may be benign such as general post workout soreness or may include more serious pathology such as tendonitis, glenohumeral instability and laxity, impingement, rotator cuff tears, labral tears, symptomatic os acromiale, scapular dyskinesis, and increased glenohumeral range of motion.[14-20]

The authors speculated that weakness or muscular imbalance of the rotator cuff and shoulder muscles are possible reasons for the shoulder pain in competitive swimmers. There is evidence in non-athlete populations that rotator cuff strengthening decreases shoulder pain. With increased shoulder strength, self-reported shoulder pain levels decrease. McClure, et al[21] implemented a six-week strength and stretching training program to study the relationship between shoulder strength changes and pain in non-swimming patients with impingement syndrome. Interventions to strengthen rotator cuff and scapular stabilizers and to increase flexibility resulted in decreased pain during external and internal rotation, as well as increased strength in these motions. However, others have found no relationship or difference between shoulder pain and strength when comparing swimmers who experience pain and those who do not.[5,18,22]

Ramsi, et al suggested that shoulder pain in collegiate-level swimmers could be the result of muscular imbalance developed during training and competition in adolescence.[23] Insufficient research has been conducted regarding the effect of competitive swimming on younger swimmers who are still developing their skills and gaining height, weight, and muscle mass. Previous authors have examined shoulder pain and its relationship to selected variables in college-age swimmers.[5,22,24] No studies have examined subjects whose mean age was below the age of 14. Bak et al reported that some swimmers (mean age 18.5 years) on the Danish National team started competitive swimming as early as age 11.[22]

Dry-land strength training is used for performance enhancement and injury prevention.[25] Krabak et al[7] surveyed coaches/trainers of randomly selected US swim clubs and found that dry-land training rates increased with age. Of those swimmers ≤ 10 years of age, 54% participated in dry-land training. By 15-18 years, 93% participated. No studies have examined the effects of dry-land training in adolescent swimmers.

The purpose of this study was to evaluate changes in shoulder strength and discomfort or soreness in a group of adolescent competitive swimmers who took part in a dry-land shoulder strengthening program and a group of swimmers who did not. It was hypothesized that no interaction would occur between experimental and control groups in shoulder strength over time and that no relationship would be found between the groups concerning changes in strength and pain levels.

METHODS

Participants

Forty-three volunteers were interviewed for participation. They were recruited from a sample of convenience from the Aqua Shocks swim team (Wichita, KS) who practiced at a local university's pool. Subjects were excluded if they had been injured or had surgery within the last six months. No volunteers met the exclusion criteria. All participants were under the age of 18, and therefore required parental consent and participant assent according to the Wichita State University's Institutional Review Board that approved this study.

Table 1. *Intratester reliability*	
Motion	Reliability
Flexion	.936
Abduction	.916
Internal Rotation	.889
External Rotation	.898
Extension	.932

Instrumentation

A hand-held dynamometer (HHD), the Lafayette Manual Muscle Test System (Lafayette Inc, Lafayette IN) was used to test each participant's isometric shoulder strength. An HHD was used because of its versatility with testing muscles at several difference angles and for its portability, and proven validity and reliability for measuring muscle strength in kilograms.[26,27] A pilot study showed examiner's test-retest reliability for measuring strength of shoulder flexion, abduction, extension, internal rotation, and external rotation was high (Table 1).

Procedure

Prior to study inclusion each participant filled out a questionnaire describing history of injury and rating their current shoulder soreness on a visual analog scale (0-10). Participants were randomly assigned to either an experimental or a control group with the role of a dice. Isometric force (in kg) was measured in the dominant arm using an HHD. Dominant arm was determined by asking swimmers which arm they would use to throw a small ball. Isometric strength of shoulder flexors, abductors, extensors, internal and external rotators was tested. Each muscle group was tested using three repetitions according to procedures described by Kendall et al.[28] A mean of the three scores was used for analysis. Testing occurred before the intervention began, and then was repeated at six weeks, and twelve weeks after onset of the exercise program. To prevent bias, the researcher testing muscle strength was blinded to group assignment throughout the study. None of the researchers was affiliated with the swimming team and, therefore, was not present at all training sessions.

After initial testing, the control group was released back to regular swim practice and instructed to continue their normal swimming regimen. The experimental group was instructed on five resistance band exercises for strengthening the shoulder and rotator cuff muscles. Exercise band resistance ranged from least resistance, yellow, to most resistance, gray. Experimental group participants were assigned a specific color depending on their initial strength assessment. Participants tried bands starting with yellow progressing as tolerated until they found a band that created difficulty between a 6 and 10 difficulty with zero being "nothing at all" to ten being "very, very hard".

Exercises for selected muscles groups were developed based on recommendations from studies demonstrating high EMG activity.[29-32] The experimental group was given handouts with explicit written instructions and pictures for exercises to strengthen shoulder flexors (Figure 1), abductors (Figure 2), extensors (Figure 3), internal (Figure 4) and external rotators (Figure 5) (Table 2). These were performed bilaterally because swimming uses both arms. Exer-

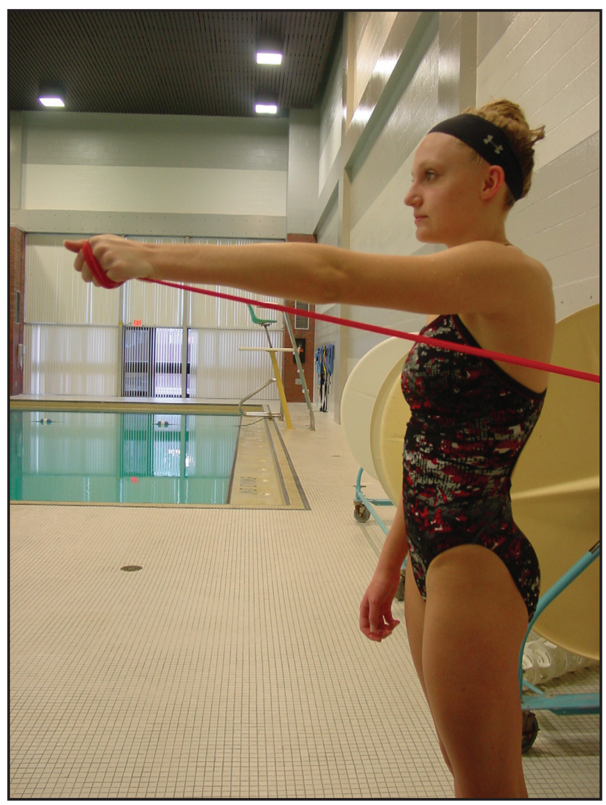

Figure 1. *Exercise position for shoulder flexion*

Figure 2. *Exercise position for shoulder abduction*

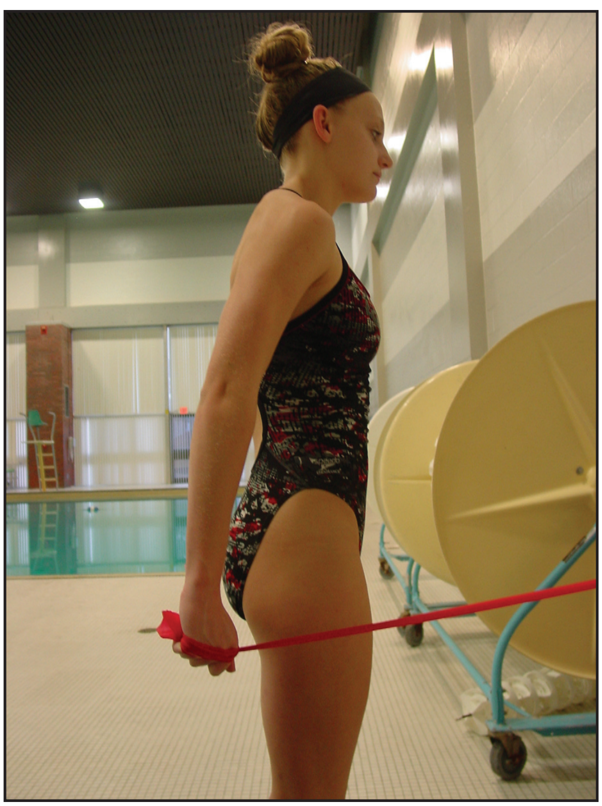

Figure 3. *Exercise position for shoulder extension*

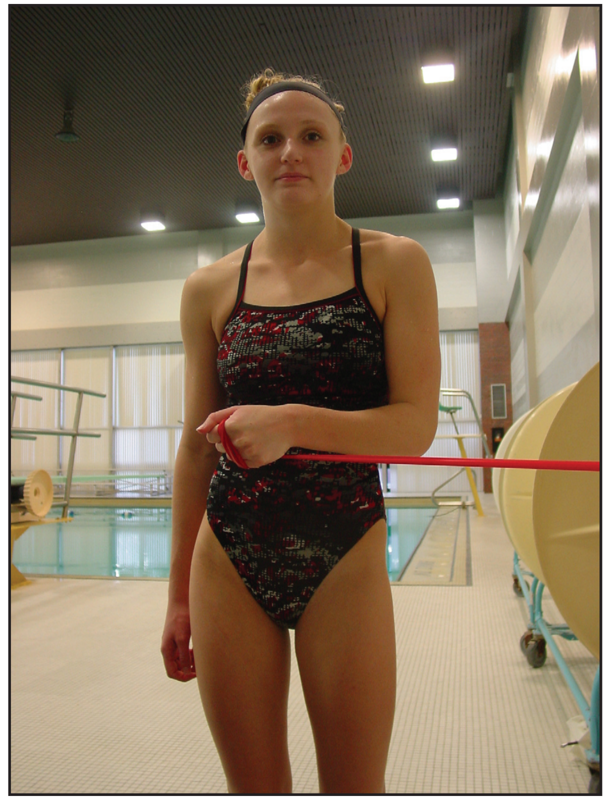

Figure 4. *Exercise position for shoulder internal rotation*

Figure 5. *Exercise position for shoulder external rotation*

Table 2. *Strengthening exercises with starting and ending positions*		
Exercise	**Starting Position**	**Ending Position**
Shoulder flexors (Figure 1)	Shoulder at 0° abduction	Shoulder at 90° flexion
Shoulder abductors (Figure 2)	Shoulder at 0° abduction with elbow bent 90°	Shoulder at 90° abduction with elbow bent 90°
Shoulder extensors (Figure 3)	Shoulder at 45° flexion	Shoulder 5-10° extension
Shoulder internal rotators (Figure 4)	Shoulder at 0° abduction, laterally rotated 10°, with elbow bend 90°	Shoulder at 0° abduction, medially rotated 50-60°, with elbow bent 90°
Shoulder external rotators (Figure 5)	Shoulder at 0° abduction, medially rotated 50-60°, with elbow bent 90°	Shoulder at 0° abduction, laterally rotated 10°, elbow bent 90°

cises were performed prior to swim practice 2-3 times per week, 2 sets of 15 repetitions. Researchers reviewed correct exercise performance every other week. To know when to increase the resistance band being used, participants rated their difficulty on the same scale described above. Participants began using a band with the next higher resistance when they rated their current exercise difficulty at $\leq$ 6 out of ten. Pain was rated using the Wong-Baker scale at baseline, 6 weeks and 12 weeks.

Data analysis

Strength scores were not adjusted to bodyweight. The three repetitions of strength measurements taken at each time were averaged. Strength data were analyzed using a mixed design two-way ANOVA. Change in strength was analyzed using univariate analysis between groups with pain at the end of the study (time 3) as the covariate. The dependent variables were isometric strength measurements (kgs) and pain scores. The independent variable was group (experimental or control). Pain ratings were analyzed between groups over time using contingency coefficients. The alpha level was set at 0.05. SPSS V. 19 was used to analyze the data.

RESULTS

Twenty-one participants completed the 12-week program. Characteristics were not different for the 43 who were initially tested and the remaining participants (Table 3). Table 3 also includes characteristics of both groups who completed the program. Twenty –two participants were lost to different swim clubs or school teams over the 12-week training program and therefore, did not complete the program. . No one left the study due to injury or pain from any of the prescribed exercises.

No differences were found between groups at the 6-week measurement timeframe in any of the analyses; therefore, tables do not include these data. For those in both groups who completed the 12-week program, strength in external rotation increased significantly between baseline and 12 weeks. The experimental group gained a greater percentage of strength in each motion, however, only gains in external rotation were statistically significant (Table 4). Ratios of external to internal rotation strength remained at approximately 0.60:1 and were not different between groups over time (data not shown).

No differences in baseline pain rating or pain ratings over time were demonstrated between those participants who completed the program and those who did not. (Table 5) To account for any pain that may have interfered with strength training, pain was used in the analysis of variance when determining if strength changes were significantly different between the control and experimental groups at the

Table 3. *Mean (SD) for participant characteristics by group*

	Participants at baseline (n=43)		Participants who completed 12 week program (n=21)		Participants who did not complete 12 week program (n=22)	
	Experimental group (n=23)	Control group (n=20)	Experimental group (n=11)	Control group (n=10)	Experimental group (n=12)	Control group (n=10)
Height in centimeters	147.56 (16.10)	150.33 (15.10)	147.04 (16.81)	148.45 (16.61)	147.95 (16.28)	152.76 (11.24)
Weight in kilograms	44.54(15.44)	44.84 (12.14)	49.10 (21.15)	43.78 (8.48)	41.27 (12.03)	45.00 (14.58)
Age in years	11.37 (2.01)	12.03 (2.27)	11.20 (2.44)	11.31 (2.24)	11.52(1.61	12.83 (2.12)

Table 4. *Mean (SD) for isometric strength measures (in kilograms) for the experimental group and the control group, mean (SD) difference within groups and mean (95% confidence interval (CI) differences between groups. Strength is reported for the right upper extremity.*

Outcome	Strength in kg				Change within groups		Difference between groups		
	Week 0		Week 12		Week 12 minus week 0		Week 12 adjusted for week 3 pain	Group difference as % of baseline	
	Exp	Con	Exp	Con	Exp	Con	Exp - con p value	Exp	Con
	N=11	N=10	N=11	N=10	N=11	N=10	N=21	N=11	N=10
Flexion	5.23 (2.06)	5.69(2.37)	5.63(2.05)	5.75 (2.52)	0.41 (.49)	0.06 (.39)	-.35 (-.047-.754) .08	9%	1%
Extension	11.57 (4.49)	11.49 (3.51)	13.81 (4.99)	13.75 (4.19)	2.23(1.60)	2.25 (1.62)	-.02 (-1.516-1.47) .98	21%	20%
Abduction	4.88 (1.97)	4.96(1.91)	5.12 (1.71)	5.28 (1.91)	0.25 (.69)	0.32 (.53)	-.08 (-.622-4.65) .77	11%	8%
Internal rotation	9.37 (4.04)	9.65(3.64)	10.97 (3.90)	10.42 (4.06)	1.60 (1.11)	0.77(1.57)	.83 (-.444-2.093) .19	20%	11%
External rotation	5.46(1.97)	5.62 (1.79)	6.65 (2.24)	6.08 (1.69)	1.19 (.55)	0.46 (0.63)	.73 (.174-1.292) .013	23%	11%

Exp=experimental group
Con=control group

Table 5. *Frequency of pain ratings of participants (choices were 0-10, in intervals of 2)*

Pain rating	Participants who completed 12 week program (n=21)		Participants who did not complete 12 week program (n=22)	
	Experimental group (n=11)	Control group (n=10)	Experimental group (n=12)	Control group (n=11)
0	8	8	6	5
2	2	1	3	3
4	1	0	1	0
6	0	1	1	2
8			1	0
12-week				
0	9	8		
2	1	1		
4	1	1		

end of the project. Only change in external rotation strength was significantly increased between groups (**Table 4**). There were no significant relationships between pain ratings and strength ratings over the 12 week study.

DISCUSSION

This is the first study to examine the effects of a dry-land strengthening program on swimmers under the mean age of 14. Strength improved in both groups in all muscles tested. However, only external rotation strength improved significantly for the experimental group over the course of the study.

Because of the role of the pectoralis major and latissimus dorsi in swimming strokes, internal rotation musculature is stronger than that of the external rotation musculature in competitive swimmers because repetitive concentric contractions are required during propulsion.[5,22,33-36] The results of the current study agree with these reports. At all measurement times, internal rotation strength was greater than external rotation. Ramsi et al found internal rotation and external rotation strength increased over time depending on side and gender, however experimental and control groups were not used as this was a cohort study who followed 27 varsity swimmers across a season.[23] With high volumes of practice yardage, it is not uncommon for the anterior shoulder to become overdeveloped leading to strength imbalances between the anterior and posterior shoulder.[37,38]

The only significant strength gains that occurred in the experimental group were of the external rotators. These gains, albeit limited, may be due to the experimental group's performance of dry-land exercises to increase the strength of these muscles. In contrast to the internal rotators, strength of the external rotators is consistently weaker in both college and masters-level swimmers. This has been attributed to the lessor role of the external rotators during swimming; external rotation is the least used motion.[5,22,33-36] The external rotators primarily function eccentrically to decelerate the humerus throughout the swim stroke.[23]

Pink et al found that the subscapularis is active throughout the freestyle stroke; while the supraspinatus, infraspinatus, and teres minor are only active during small portions of stroke and at a lower level of muscular activation.[39] According to Scovazzo et al[4], the infraspinatus demonstrates a significantly higher level of muscular activation when shoulder pain occurs with swimming. Weak external rotators in swimmers has been recognized as a contributor to common shoulder conditions such as impingement, tendinitis and instability.[13,16,33,36,37,40] Thus, an increase in external rotation strength may decrease a swimmer's chance of developing impingement.

Strength gains by all participants were anticipated over 12 weeks as the act of swimming by nature should create a physical response to gain shoulder strength or endurance. However, it was expected that experimental group members would demonstrate strength increases in more than just the external rotation. McClure etal[21] recruited subjects with impingement syndrome from a university swim team. Their strengthening and stretching program for rotator cuff and scapular stabilizers resulted in strength gains over six weeks. Hibberd et al[38] conducted a 6- week strengthening and stretching program on shoulder and scapular-stabilizer strength and found no change in strength in flexion, extension, internal and external rotation between the experimental and control groups. However, shoulder extension and internal rotation strength significantly increased in all subjects regardless of group assignment. Swanik et al[41] found no significant isokinetic strength differences between control and intervention groups after a 6-week functional training program that included rubber-tubing, dumbbell, and body-weight exercises. Researchers attributed lack of significant changes in strength variables between groups to preseason conditioning. Despite lack of strength changes between groups, the experimental group reported fewer injuries and reduced rate of increased shoulder pain.[41] Swanik et al suggest that although strength did not improve, the program was a success.[41]

Controversy remains regarding the assessment of strength ratios. Some researchers report higher internal rotator/external rotator ratios in competitive swimmers. Internal to external rotation strength ratios approximate 3:2 in both non-athletes and athletes, including college and masters level swimmers.[5,33,42,43,44] Bak et al[22] examined strength ratios by evaluating both concentric and eccentric external rotation/internal rotation ratios. In those elite swimmers with one symptomatic and one nonsymptomic shoulder or control, strength ratios were 0.66 to 0.83. Bak et al agree with Beach and colleagues, who found similar strength ratios of 0.64 in elite collegiate swimmers.[5] Control subjects in other studies had an external/internal concentric isokinetic strength ratio of 0.75.[33,45]

The current results conflict with those of Ramsi et al who found an approximate 1:1 ratio between internal rotation/external rotation strength in competitive high school swimmers throughout the swimming season.[23] Magnusson et al[46] also observed at 1:1 strength ratio between internal rotation/external rotation strength in masters level swimmers. There are at least two reasons for the current findings of external rotation/internal rotation strength of 0.60:1 in both groups. First, all of the swimmers were adolescent competitive swimmers who may not yet have achieved significantly stronger internal rotation strength. Substantial strength changes may take months or years to develop. Second, while the experimental group's strength in external rotation increased significantly, both groups' external rotation strength improved the current participants made statistically significant gains in external rotation strength, which may limit a change in the ratio.

Baseline pain ratings were not different between those participants who completed the program and those who did not, nor were differences found between experimental and control groups over time (Table 4). When pain at 12 weeks was used as the covariate, only change in external rotation strength was significantly increased between groups (Table 3). Change in pain rating and strength were not related (data not shown). This is somewhat surprising as shoulder pain in competitive swimmers has been reported to be present at all participation levels.[5,13,17,18,19,22,38] The participants in the present study were adolescent competitive swimmers who may not have participated in sufficient practice/competition to develop shoulder pain. Studies describing shoulder pain usually have examined high school age or older swimmers. High reports of swimmers with shoulder pain may be misleading and give a false impression that even younger competitive swimmers suffer shoulder pain.

This study was not without limitations. The largest was the small sample size. Only 21 of 43 the original participants completed the study. More than half of the initial participants left near the end of the season to join other swim teams. Swimmers did not keep training logs; it was assumed that experimental group members were performing the exercises at least two to three times per week per instructions. Swim coaches indicated they reminded swimmers to perform exercises before each practice. Use of the Wong-Baker pain scale may have forced participants to pick a pain rating in even numbers to correspond to the faces depicted on the scale. Future studies should use a more typical visual analog scale presented in centimeters to be more accurate and not inadvertently lead participants to a certain pain rating. Lastly this study examined strengthening in younger adolescent male and female swimmers. Most previous studies have utilized older (high school and collegiate) competitive swimmers. Although the present study assessed competitive swimmers, obvious differences exist between a preteen competitive swimmer and a 22-year-old collegiate competitive swimmer. These differences could explain the current findings. The participants were younger; therefore, their pain level was likely lower due to a less demanding training schedule based upon participant's age. The strengthening program may have produced effects that are more robust if it lasted the entire season rather than only 12 weeks. Swimmers are often taught that shoulder pain is normal in their sport, therefore, it is possible that subjects who were experiencing shoulder pain under-reported their symptoms. Lastly, individual effort could not be assessed. Although the exercise program was clearly explained and researchers visited every two weeks to evaluate tubing resistance and exercise form, some participants may have chosen tubing that did not sufficiently challenge them and, thus, did not create a training effect.

Future research should examine injury prevention of adolescent swimmers using both a strengthening and a stretching program. Larger sample sizes and higher reports of pain and soreness will be important to finding any possible relationship between pain and strength in this age group.

CONCLUSION

Strength training is common in swimmers. Younger swimmers are now asked to perform dry land strength training. Adolescents who perform shoulder strengthening significantly increased their external rotation strength compared to adolescents who only participated in a regular swimming regimen. Increasing strength of external rotators in swimmers may be helpful as a preventative measure to help decrease injury risk.

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